A NEW LOOK AT PHONOTACTICS

by Sydney M. Lamb

The relational network notation commonly used by the cognitive-stratificational school consists of interconnected lines and nodes that allow activation to proceed in either direction. The lines are thus two-way lines and the nodes are two-way nodes. The structural status of these two-way lines and nodes has not generally been made explicit, but some further specification is necessary to provide an exact account of how impulses travel through the network in the processes of speaking and understanding. Peter Reich (1968, 1970) has analyzed the nodes as finite state machines, while I (in various unpublished lectures and notes dating from 1966) have preferred to analyze them as having internal structures representable in another network notation, sometimes called the "micro-notation." In the micro-notation, all lines are one-way—that is, they allow passage of impulses in one direction only—and all the nodes are one-way nodes. The lines and nodes of the micro-notation are thus, appropriately, simpler than those of the "macro-notation." According to my view, the macro-notation is just a shorthand for what is more accurately, but more cumbersomely, representable in the micro-notation. The macro-notation is also useful just because it is less precise and therefore less demanding: it can be used in cases where the correct analysis in terms of micro-nodes may be uncertain, just as the verbal or tabular account is useful in cases where it is not yet clear how to represent a structure in the more demanding (macro-) relational network notation.

The internal structures of some of the macro-nodes consist simply of oppositely directed pairs of (one-way) micro-nodes, while others are more complex; and according to one hypothesis, one type of ordered AND is not really a node at all in the one-way notation (see figure 1). Various hypotheses of the internal structures of the nodes have been presented in lectures during the past ten years or so, but only two have been published, as far as I know (Christie 1977, 1978).

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Figure 1 illustrates the micro-structure for a small fragment of English phonotactics described in terms of segments (rather than of components, which is probably ultimately a better way to do it). This fragment specifies that at a particular tactic position X there can occur (as alternative to another option not shown) /t/ or /d/ followed optionally by /r/. At left we have the conventional shorthand notation, and at right we have its analysis. Note that the downward AND of the shorthand notation is represented only by lines in the analysis rather than by any node, while the downward OR nodes consist of two one-way nodes each.

Some readers may wonder why the activation returns to point X after the /tr dr t d/. The answer is, so that it may proceed to whatever comes next, in the same way that it proceeded from /t d/ to the optional /r/ (via the line that directly represents the concatenation shown indirectly by the downward AND of the shorthand notation).

If we accept the hypothesis that the real structure of the relational networks consists of one-way lines and nodes, then the use of the two-way shorthand notation is in keeping with an assumption that has generally gone unstated:
that the (one-way) lines of cognitive linguistic networks generally occur in complementary pairs, and that the (one-way) nodes occur in a small number of recurrent simple configurations. This assumption may be called "the two-way hypothesis" or "the divided highway hypothesis." To be sure, it has been recognized for some years now that some one-way lines and nodes occur that are not so paired. The enabling lines and nodes are the best-known examples. They are employed, for example, in Lockwood's textbook (1972). The divided highway hypothesis is thus not absolute—it is rather a hypothesis about what kind of structure predominates.

I have harbored vague suspicions for several years that the occurrence of such non-paired one-way lines and nodes is really more widespread, and that tactic patterns, in particular, may be made up predominantly if not entirely of such non-paired one-way lines and nodes. This view may be called "the one-way hypothesis." I also suspected that it might take a lot of time to develop and test the hypothesis, as it might lead to sweeping revisions of cognitive-stratificational theory. So I delayed while looking for a large block of time to come along. It never did, but when I saw the comparison shown in figures 2 and 3 in Eli Fischer-Jørgensen's recent book on phonological theory (1975:312-313), it was apparent that I should wait no longer.

Fischer-Jørgensen presents these two figures with the following comments:

Fig. [2] is a graphical representation of a subset of the phonologically possible syllable onsets in English, namely: /pl, bl, kl, gl, pr, br, tr, dr, kr, gr, sl, sm, sn, spl, skl, spr, str, sp, st, sk/ and any single consonant of the above, namely /p, t, k, b, d, g, s, l, r, m, n/. The full set would have been considerably more complicated.

It would probably be easier to read the list given above or the following statement: "All consonants p, t, k, b, d, g, s, l, r, m, n occur alone. Clusters of two consonants consist of either (1) s + any nasal or l or any voiceless stop, or (2) any stop + r, or (3) any labial or any velar stop + l. Clusters of three consonants consist of s + any of the two-consonant clusters starting with a voiceless stop."

It would also be possible to represent the same facts graphically in a much simpler way, e.g. as in Fig. [3] (which has been inspired by Bengt Sigurd's phonotactic diagrams).

It is quite clear, as Fischer-Jørgensen suggests, that the second diagram is simpler than the first, and the main reason, as I shall proceed to demonstrate, is simply that the divided highway hypothesis forces needless complexity into phonotactic networks.

But first I am obliged to point out that Fischer-Jørgensen's comparison is not entirely fair, as Lockwood's diagram conveys more effective information. It is a fundamental principle of cognitive-stratificational linguistics (in keeping with an equally fundamental principle of glossematics) that measures of relative simplicity of alternative descriptions are appropriate only if they convey the same effective information. This point is often neglected, but it is surprising to see a longtime fellow-admirer of Hjelmslev overlook his famous "empirical principle."
One might hope it would be obvious that great care must be taken in comparing descriptions that are given in different notation systems. In such cases it is essential to distinguish the differences in notation from those involving the information conveyed. Fischer-Jørgensen’s verbal account is not just a translation from Lockwood’s diagram into words, but a different account, as may be seen if we translate into relational network notation.

Turning now to Fischer-Jørgensen’s diagrammatic account, we see that
it differs from Lockwood's with respect to several kinds of effective information. For one thing, Fischer-Jørgensen's diagram is merely a representation of the data, while Lockwood's attempts to represent the structure that is responsible for the data in a form that can fit into a uniform account of the larger structure of which it is a part, that can potentially satisfy certain requirements of the theory. These requirements include: (1) the account must potentially provide the basis for a model of the processes of language use: production, understanding, and learning; (2) It must make use of a formal notation having explicitly definable properties, including a measure of surface information for use in comparing alternative descriptions that convey the same effective information.

For our present purposes it will not be necessary to concern ourselves with how the phonotactic structure fits into the overall structure—in particular the sign pattern that accounts for all the individual meaningful phonological sequences that instantiate the general patterns of the phonotactics. It will suffice to add three kinds of specifications to Fischer-Jørgensen's diagram. The first is a simple mechanical conversion to a notation having the desired formal properties, especially that of providing for measurement of relative simplicity. We can then add the necessary effective information concerning what phonotactic possibilities are being accounted for.

Figure 4 shows the result of the notational conversion. The notation is like that which is familiar in relational network theory except that in this case the lines are one-way lines and the nodes are one-way nodes—the direction is from left to right.³
By the simple well-known principles for simplifying networks, as described for example by Reich (1968) and by Lockwood (1972), this diagram may be simplified to yield figure 5. And here we should not miss a rather striking observation: Figure 4, for all its seeming simplicity, is not simple at all in comparison to the raw data—it fails to capture any generalizations other than those which automatically follow from recognizing segments. (Those generalizations are represented by the OR nodes in figure 4. The alternative would be the failure to recognize that, e.g., the /s/of/sm/ is the same as that of /sn/.) Figure 5 is simpler because it conveys two generalizations: (1) /p b k g/ are similar with respect to what can follow; (2) /l r/ are similar with respect to what can precede (namely, both can be preceded by /p b k g/). Figure 5 states these as general facts, while figure 4 treats the individual cases as separate facts. This example provides a good illustration of the simplicity principle as stated in my "Prolegomena to a Theory of Phonology" (1966), to the effect that true simplicity results from generalization. The principle as stated there, however, fails to deal with another type of situation that concerns us in the present paper: that in which a description is needlessly complex not because it fails to capture generalizations from the data but because it is based upon an assumption or a notation that forces complexity into the description when it is not in the data at all. This type of complexity is the main basis for my repeated criticisms of transformational generative grammar (e.g., Lamb 1975), and it is also the culprit in figure 2—not through any fault of Lockwood's, I hasten to add, other than that of having followed the teachings of one of his
teachers. In other words, apart from the difference in effective information, Fischer-Jørgensen’s account is simpler than Lockwood’s not because Fischer-Jørgensen has captured any generalizations but because Lockwood followed a hypothesis that introduced excess baggage into the description. That point, however, has yet to be demonstrated.

We are now ready to add the necessary effective information to the account. Two types of additional effective information may be distinguished. The first kind (figure 6) concerns the question of what can follow the various consonants and consonant clusters. The closing OR node at the right has the effect of stating that all of the various clusters and consonants are alike with respect to what can follow (namely, a vowel). We must also add the line labeled 1 to account for the fact that /s/ need not be followed by another consonant, and line 2 to account for the fact that the stops need not be followed by /l/ or /r/. These latter facts are presumably not actually in conflict with Fischer-Jørgensen’s diagram, but the trouble is that her version fails to make them explicit. We are presumably allowed to read the diagram in such a way that we can stop with any of the consonants—or rather, we can proceed from any of them to a vowel—instead of following one of the lines to the right. But if so, this situation is not distinguished from the contrary one, that of limited distribution—which also occurs in phonotactic structures, even though it is not present in the data of our example. For example, after certain vocalic nuclei in English one is obliged to go to a final consonant or cluster, while for others we are free either to do that or to proceed to the end-of-syllable position.

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**FIG. 6. FIGURE 5 PLUS ADDITIONAL EFFECTIVE INFORMATION:** (1) /s/ need not be followed by another consonant; (2) /p b k g t d/ need not be followed by /l/ or /r/.
The second kind of additional effective information concerns what can precede the various consonants and clusters. Figure 7 recognizes possibilities other than initial /s/ and also shows that all of the various consonants and clusters are alike with respect to what they follow—that is, in each case we are starting from the same position, namely syllable-initial position. (Also, because it is simpler as well as correct to do so, the diagram allows for the possibility of having no initial consonant at all.)

We now have a diagram that can be validly compared with Lockwood’s, as figure 7 and figure 2 convey the same effective information, except for the minor difference that figure 7 allows for zero initial consonant. (Figure 2 may appear to be easier to incorporate with the associated sign pattern, but figure 7 can in fact easily be adapted to such use without additional surface information.) In making the comparison it is necessary to keep in mind that all the lines and nodes of figure 7 are actually simpler than those of Lockwood’s diagram, since the latter are two-way lines and nodes—i.e., they are complex.

To make an accurate comparison we need to put the two diagrams into the same notation. It is not possible to convert figure 7 into the notation of figure 2 since the lines of figure 7 do not occur in complementary pairs. But figure 2 can be converted to the notation of figure 7, since to do so requires only that figure 2 be represented as one-way lines, and such a representation is more accurate anyway than that of figure 2, which is only a shorthand representation.

As a first step in the notational conversion, we may take figure 1, which is now seen to be a portion of the account of figure 2. The whole of figure 2 could be analyzed in the manner of figure 1, but the resulting diagram would be rather unwieldy. It will be easier to work with the diagram if we pull it apart in the manner shown in figure 8, in which each of the lines is labeled with a number for ease of comparison. Note that in figures 1 and 8 the direction is indicated by the nodes, which subtly suggest arrowheads, while in 8b this device is dropped in favor of the convention that the direction of a line is from left to right unless otherwise specified. In this case we have, then, the same notational conventions as in figure 7.

The conversion of figure 2 to this notation is shown in figures 9, 10, and 11. Figure 9 shows the converted form of line a leading down from node 1 of figure 2 (i.e., the leftmost branch) and its succedents. Notice that the right half of figure 9 is a mirror image of the left half. If this mirror-image effect were present for the entire diagram in its simplest form, then the divided highway hypothesis would be supported: Figure 9 (taken in isolation from the rest of phonotactics) lends itself, because of its mirror-image effect, to a generalization that the one-way lines and nodes occur in complementary pairs. (Whether, if the divided highway hypothesis were to survive, these pairs should be represented as divided highways as in figure 1b or as spaced out in the manner of figure 8b is of course purely a matter of notational convenience.)

Let us now consider line b of node 1 (the second main branch) in figure 2.
Fig. 7. Figure 6 plus additional effective information of the second kind: starting possibilities other than /s/.
Fig. 8. Pulling apart figure 1. Figures 1b, 8a, and 8b are isomorphic, while figure 1a is a shorthand representation of 1b (and therefore also of 8a and 8b). The four figures are thus identical in both effective and surface information, differing only in superficial information.
Fig. 9. Conversion to one-way notation of branch a of node 1 of figure 2, and its succedents. Nodes are numbered for ease of comparison with figure 2.

Fig. 10. Branches a and b of node 1 of figure 2, and their succedents, converted to one-way notation.
FIG. 11. THE WHOLE OF FIGURE 2 CONVERTED TO ONE-WAY NOTATION. THIS DIAGRAM HAS THE SAME EFFECTIVE AND SURFACE INFORMATION AS THAT OF FIGURE 2.
Notice that the AND node is represented in figure 10 as no node at all, just as we have seen in the case of figure 1. In the one-way diagram this specification of concatenation is given directly by the one-way lines themselves.

We now encounter a minor but interesting problem. We may consider it in relation to node 2 (of figures 2 and 10). Upon returning from /m n/ (in figure 2)—or, in figure 10, upon proceeding to the right from /m n/ to the opening node 2—which path do we choose? In terms of figure 2 do we or do we not stipulate that the exit path (upon return to 2) must be the same as the entering path? If so, additional structure is required beyond that shown in figure 10. If not, a free choice is provided, and the exit path could be different from the entering path. The way to answer the question is to find out whether it makes a difference. If we proceed upwards from node 2 in figure 2 along either line, we find that they both go to the same place—node 1. (This would not be the case under some hypotheses, which impart internal structure to the ordered AND that would block an upward impulse just above node 4 if it were not a returning impulse. That hypothesis amounts to one means of providing the additional structure that in some cases effectively limits free choice upon going upward through upward ORs.)

Now if we similarly check every upward OR in the Lockwood diagram we find the same thing—in each case it makes no difference which of the two paths we choose, since they both go to the same place. For example, going upward from node 6, we can take the left path up to the AND, which leads to node 8, or we take the right path to node 18 and on to another AND, which sends us to the same point 8. This finding strongly suggests that the diagram incorporates redundant information.

Since it makes no difference in the present situation which branch is taken, we omit any additional choice-specifying structure from figures 9, 10, and 11.

If we now convert the remainder of figure 2 to the one-way notation, the result is figure 11.

It is now appropriate to ask whether figure 11 can be simplified. To be sure, it looks more complex than figure 2, but that is because we have converted to a notation that shows more structure. On the other hand, if the two-way hypothesis were justified, it would mean that the best notational simplification of figure 11 would be the conversion back to figure 2. The real question is, then, can it be simplified other than by collapsing the mirror images to yield figure 2? To the extent that it can, we have support for the one-way hypothesis.

Now even a very casual glance at figure 11 makes the answer quite obvious to anyone who has worked with relational network diagrams. At the right end, the three closing OR nodes 5, 4, and 1 can be collapsed, as can the closing ORs 18 and 8 in the middle. Also, in all those cases of opening ORs in which it makes no difference which path is taken, one of the lines may be removed along with the OR. These opening ORs correspond to the upward paths through the upward ORs in figure 2, and we have already noted that in every
case it makes no difference. Notice, for example, reading from the right-hand end of figure 11 leftward, node 8, node 10, and node 15.

These simplifications result in figure 12, in which it can be seen that as soon as they have been made, the way is clear for further simplifications. The simplifying process may be continued through several steps, which are here left as an exercise for the reader, until we arrive at none other than figure 7, the same one arrived at by adding effective information to Fischer-Jørgensen's account. The only difference in effective information between figures 7 and 11 is that the former also allows for zero initial consonant, as I mentioned earlier. And if we now examine figure 7 to see whether we can find any remaining mirror-image effect, what we find is little or none, a devastating finding for the divided highway hypothesis.

We must then ask two related questions: First, why? Second, is this finding peculiar to the data of our example, or is it generalizable? An answer to the first of these questions will take us a long way toward that of the second. To answer the first, we have to consider just what is involved in the generalizations that lead to phonotactic descriptions. Generalizations are based upon shared distributional properties or shared sets of environments. For our present purposes, we need to distinguish three kinds of such generalizations. Those of the first kind are based on shared predecessors or left-neighbors. For example, /l/ and /r/ resemble each other in that both can be preceded by /p b k g/. These generalizations are represented in the one-way diagrams by opening OR nodes. Generalizations of the second kind are based upon shared right-neighbors; i.e., similarity with respect to what can follow. For example /p b k g/ resemble each other in that they can be followed by /l r/. These generalizations are represented by closing OR nodes. Generalizations of the third kind are based upon similarity with respect to both left-neighbors and right-neighbors. For example, /p/ and /k/ are alike in that both can be preceded by /s/ and followed by /l r/. Generalizations of this kind are represented by downward ORs in the two-way notation, and by both opening and closing ORs in the one-way notation. But we see that in the process of simplification leading from figure 11 to figure 7, most of these nodes fall away. Thus nowhere in figure 7 do we find a grouping of /p/ and /k/.

In order for the two-way hypothesis to be supported, there would have to be a large degree of agreement between the generalizations of the first kind and those of the second kind. These would automatically correspond also to the generalizations of the third kind, and to treat those of the first two kinds as separate would be redundant.

The one-way tactics, on the other hand, treats only the generalizations of the first two kinds, and the one-way hypothesis succeeds to the extent that they do not duplicate each other. What the simplification of the Lockwood diagram has shown us is that generalizations of the first two kinds are largely independent of each other. For example, /p b k g/ exhibit similarity with
Fig. 12. Simplification of Figure 11 (first steps). Nodes that have fallen away in the process of simplifying are indicated with dotted lines. Cases of collapsed nodes are indicated by double numbers (e.g., 15/17). Continued simplification eventually results in Figure 7.
respect to what can follow but not with respect to what can precede. The divided highway hypothesis forces the recognition of distribution classes that are the intersections of those based on generalizations of the first two kinds—for example, the class consisting of /p k/. To put it another way, the divided highway hypothesis forces a considerable amount of surface information into the account—surface information that does not contribute to the effective information.

Now we can ask whether the findings from the example at hand can safely be generalized. Preliminary observation suggests that further phonotactic studies like this one will come to similar conclusions, i.e., that generalizations of the first kind will fail to show enough correspondence with those of the second kind to justify the two-way hypothesis. Whether the one-way hypothesis can be extended to morphotactics is a separate question, best left for another paper, but definitely to be asked in view of the present findings.

And finally we may ask, in view of the great relative complexity of diagrams based on the divided highway hypothesis, why did we ever get involved in using them in the first place? The answer is that we were influenced too much by our predecessors and contemporaries—those who were doing immediate constituent analysis and tactic descriptions using phrase structure rules. The two-way notation for tactics is just the simple result of a mechanical conversion of context-free phrase structure grammars into relational network notation, as has been detailed in a paper by Peter Reich (1968). Before I got into relational networks, I was using context-free phrase structure rules and tree diagrams, and I was thinking about tactics in ways influenced by that notation. In other words, the needless complexity forced upon tactic descriptions by what I have called the divided highway hypothesis is present also in any phonotactic description based on immediate constituents or context-free phrase structure rules. It is not a product of relational network notation. On the contrary, another of the beautiful features of network notation is that it allows us clearly to see the needless complexity of the inefficient method and to achieve the simplification I have proposed in this paper.

NOTES

1. The term "really" here is used in keeping with the economy theory of knowledge. It is intended to imply that the situation will be found in that account which maximizes effective information while minimizing surface information.

2. I started to draw a relational network version (macro-notation) of Fischer-Jærgensen's verbal account, but it got so complicated that I gave up. Those who need convincing that it is indeed more complicated than Lockwood's account are invited to try this exercise for themselves. It will bring home the value of relational network notation in providing an easy way to choose among competing descriptions on the basis of their relative simplicity (or the relative degrees to which they capture generalizations, which is another way of saying the same thing). By contrast
the notoriously imprecise notation of ordinary language fails to provide any easy way to know which of various alternatives is simpler/more general.

3. In the case of recursive structures we need lines that go from right to left. They can be marked as such by arrowheads.

4. Note that clusters with /y w/ were omitted from Lockwood’s diagram, which was not intended to be complete, and so are also omitted in Fischer-Jørgensen’s and throughout this paper.

5. Figure 2 gives the superficial appearance of being easier to connect to the additional network structure that would attach to its lower end, where the symbols m, n, p, . . . appear, but this illusion is easily overcome if we recall that linguistic networks are three-dimensional and that the tactic patterns are commonly conceived of as lying on horizontal planes, which are orthogonally intersected by the realizational lines. The reader who may still have doubts will be reassured by the remaining portion of this paper, which sets forth a simple step-by-step route from figure 2 to figure 7 in which none of the steps involves any change in effective information except that, as noted, in moving from figure 12 to figure 7 we introduce the possibility of zero initial consonant. The points along this route, from beginning to end, are: (1) Figure la (part of figure 2), (2) figure 1b, (3) figure 8a, (4) figure 8b (part of figure 11), (5) figure 12, (6) figure 7. The steps from (1) to (4) do not even involve any difference in surface information. Any readers who find figure 2 more attractive or more satisfying in some way than figure 7 are obliged to ask themselves at what point along this route they become uncomfortable, and why.

6. It will be seen in what follows that as soon as figure 9 is incorporated into the larger structure, some of its nodes fall away in an automatic simplification process, so that the mirror-image effect disappears.

7. There are, however, cases in other tactic patterns in which it does make a difference—and for those some additional structure is of course needed, in the form of (one-way) AND nodes. These cases appear to be just the ones in which immediate constituent structure is important. But the present example reflects the general situation in phonotactics.

REFERENCES CITED


